

UNITED STATES PATENT APPLICATION FOR:

**FILTERED ACTUATOR PORT FOR HYDRAULICALLY ACTUATED DOWNHOLE
TOOLS**

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**FILTERED ACTUATOR PORT FOR HYDRAULICALLY ACTUATED DOWNHOLE
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CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of co-pending U.S. patent application serial no. 10/073,685, filed February 11, 2002, which is a continuation-in-part of U.S. patent application serial no. 09/858,153, filed May 15, 2001, now abandoned, which is a divisional of U.S. patent application serial no. 09/435,388, filed November 6, 1999, which is now U.S. Patent No. 6,253,856, issued July 3, 2001. All of which are herein incorporated by reference in their entireties.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] This invention is related to downhole tools for a hydrocarbon wellbore. More particularly, the invention relates to an apparatus useful in conducting a fracturing or other wellbore treating operation. More particularly still, this invention relates to a filtered inlet port through which a wellbore treating fluid such as a "frac" fluid may be pumped without obstructing the workings of a hydraulic tool.

Description of the Related Art

[0003] In the drilling of oil and gas wells, a wellbore is formed using a drill bit that is urged downwardly at a lower end of a drill string. When the well is drilled to a first designated depth, a first string of casing is run into the wellbore. The first string of casing is hung from the surface, and then cement is circulated into the annulus behind the casing. Typically, the well is drilled to a second designated depth after the first string of casing is set in the wellbore. A second string of casing, or liner, is run into the wellbore to the second designated depth. This process may be repeated with additional liner strings until the well has been drilled to total depth. In this manner, wells are typically formed with two or more strings of casing having an ever-decreasing diameter.

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[0004] After a well has been drilled, it is desirable to provide a flow path for hydrocarbons from the surrounding formation into the newly formed wellbore. Therefore, after all casing has been set, perforations are shot through the liner string at a depth which equates to the anticipated depth of hydrocarbons. Alternatively, a liner having pre-formed slots may be run into the hole as casing. Alternatively still, a lower portion of the wellbore may remain uncased so that the formation and fluids residing therein remain exposed to the wellbore.

[0005] In many instances, either before or after production has begun, it is desirable to inject a treating fluid into the surrounding formation at particular depths. Such a depth is sometimes referred to as "an area of interest" in a formation. Various treating fluids are known, such as acids, polymers, and fracturing fluids.

[0006] In order to treat an area of interest, it is desirable to "straddle" the area of interest within the wellbore. This is typically done by "packing off" the wellbore above and below the area of interest. To accomplish this, a first packer having a packing element is set above the area of interest, and a second packer also having a packing element is set below the area of interest. Treating fluids can then be injected under pressure into the formation between the two set packers.

[0007] A variety of pack-off tools are available which include two selectively-settable and spaced-apart packing elements. Several such prior art tools use a piston or pistons movable in response to hydraulic pressure in order to actuate the setting apparatus for the packing elements. However, debris or other material can block or clog the piston apparatus, inhibiting or preventing setting of the packing elements. Such debris can also prevent the un-setting or release of the packing elements. This is particularly true during fracturing operations, or "frac jobs," which utilize sand or granular aggregate as part of the formation treatment fluid.

[0008] Prior solutions to the debris problem have included running in a filter or screen above the down-hole tool. This has several disadvantages. First, once the screen is run above the down-hole tool, full pressure can no longer be transmitted to

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the piston. Second, emergency release mechanisms and other devices actuated by a ball cannot be used.

[0009] There is, therefore, a need for a hydraulic down-hole tool which does not require a piston susceptible to becoming clogged by sand or other debris.

SUMMARY OF THE INVENTION

[0010] The present invention generally discloses a novel actuator port for use in a hydraulic wellbore tool, a method of making the actuator port, and methods of using the actuator port. The actuator port filters out particulates so they do not obstruct the workings of the actuator. The filtered port may comprise fine slots disposed through a wall of a mandrel spaced around the circumference of the mandrel.

[0011] The present invention introduces a hydraulic tool for use in a wellbore, comprising: a tubular wall for separating a first fluid containing region from a second fluid containing region, the tubular wall including a filter portion; and an actuating member disposed within the second fluid containing region, the actuating member operable upon contact with a fluid flowing from the first fluid containing region and through the filter portion.

[0012] The present invention discloses forming at least one filter slot in the tubular wall utilizing manufacturing methods including but not limited to electrical discharge machining and laser cutting.

[0013] The present invention may be incorporated into any kind of hydraulic tool, including but not limited to a packer comprising a packing element and a fracture valve comprising a fracture port. These may be provided into a pack-off system comprising an upper packer, a fracture valve, and a lower packer all utilizing the present invention. The pack-off system may include other components as well.

[0014] The pack-off system utilizing the present invention may be run into a wellbore where the packing elements are set and the fracture port is opened by

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injecting fluid into the packer system under various flow rates resulting in various pressures. Further, an actuating fluid may be used to set the packers and open the fracture valve, and then treatment fluid may be injected through a fracture port into the wellbore.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0016] Figure 1 is a view of one cross-section of a hydraulic packer utilizing a filtered actuator according to one embodiment of the present invention. Figure 1A is a section of Figure 1 detailing a filtered inlet port. Figure 1B is a cross-sectional view of a nozzle valve.

[0017] Figure 2 is a cross-sectional view of a fracture valve utilizing a filtered actuator according to one embodiment of the present invention. Figure 2A is an enlargement of a piston / mandrel interface of Figure 2.

[0018] Figures 3A-3D are section views of a completed pack-off system. Figure 3A is the system in the run in position. Figure 3B is the system after the nozzle valve has been closed. Figure 3C is the system after the packers have been set. Figure 3D is the system after opening of the fracture valve.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0019] FIG. 1 presents a sectional view of a hydraulic packer 1 as might be used with a filtered port of the present invention. The packer is seen in a run in

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configuration. The packer **1** first comprises a packing element **40**. The packing element **40** may be made of any suitable resilient material, including but not limited to any suitable elastomeric or polymeric material. Actuation of the packing element below a workstring (not shown) is accomplished, in one aspect, through the application of hydraulic pressure.

[0020] Visible at the top of the packer **1** in FIG. 1 is a top sub **10**. The top sub **10** is a generally cylindrical body having a flow bore therethrough. The top sub **10** is threadedly connected at a top end to the workstring (not shown) or a fracture valve (as shown in FIG. 2). At a lower end, the top sub **10** is threadedly connected to an element adapter **20**. The element adapter **20** defines a tubular body surrounding a lower portion of the top sub **10**. An o-ring **13** seals a top sub **10** / element adapter **20** interface. At a lower end, the element adapter **20** is threadedly connected to a center mandrel **15**. The center mandrel **15** defines a tubular body having a flow bore therethrough. The lower end of the element adapter **20** surrounds an upper end of the center mandrel **15**. One or more o-rings may be used to seal the various interfaces of the packer **1**. In one embodiment, an o-ring **12** seals an element adapter **20** / center mandrel **15** interface.

[0021] The packer **1** shown in FIG. 1 also includes a packing element compressor **30** and a piston **45**. The packing element compressor **30** and the piston **45** each generally define a cylindrical body and each surround a portion of the center mandrel **15**. An o-ring **14** seals a packing element compressor **30** / center mandrel **15** interface. An upper end of the piston **45** is disposed within and threadedly connected to the packing element compressor **20**. An o-ring **16** seals a packing element compressor **30** / piston **45** interface. Surrounding a lower end of the packing element compressor **30** and threadedly connected thereto is an upper gage ring **5**. The upper gage ring **5** defines a tubular body and also surrounds a portion of the piston **45**. At a lower end, the upper gage ring **5** comprises a retaining lip that mates with a corresponding retaining lip at an upper end of the packing element **40**. The lip of the upper gage ring **5** aids in forcing the extrusion of the

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packing element 40 outwardly into contact with the surrounding casing (not shown) when the packing element 40 is set.

[0022] At a lower end, the packing element 40 comprises another retaining lip which corresponds with a retaining lip comprised on an upper end of a lower gage ring 50. The lower gage ring 50 defines a tubular body and surrounds a portion of the piston 45. At a lower end, the lower gage ring 50 surrounds and is threadedly connected to an upper end of a center case 55. The center case 55 defines a tubular body which surrounds a portion of the piston 45. Within the center case 55, the piston 45 defines a chamber 60. Corresponding to the chamber 60 is a filtered inlet port 65 disposed through a wall of the center mandrel 15. Preferably, the filtered inlet port 65 comprises two sets of filter slots.

[0023] Each filter slot 65 is configured to allow fluid to flow through but to prevent the passage of particulates. Preferably, the filter slots are substantially rectangular in shape. In one embodiment shown in FIG. 1A, ten filter slots 65 are equally spaced around the entire circumference of the center mandrel for each set of inlet slots. The filter slots 65 can be cut into the center mandrel 15 using a laser or electrical discharge machining (EDM). The dimensions and number of slots may vary depending on the size of the particulates expected in the fracture fluid. As an example, for a fracture fluid with a minimum particulate size of 0.016 inch in diameter, each filter slot 65 would preferably be 0.9 inch long and between 0.006-0.012 inch wide. Optionally, the width of the slot 65 may be reduced down to 0.003 inch or as far as current manufacturing technology will allow. Typically, a maximum slot width of 0.02-0.03 inch would be expected, however, a width of 0.2 inch would also fall within the scope of the present invention. Use of the term "width" does not mean that the slot 65 must be rectangular. Other shapes can be used for the filter slots 65, such as triangles, ellipses, squares, and circles. In those cases the "width" would be the smallest dimension across the slot 65 (not including the thickness of the slot through the mandrel 15). Other manufacturing techniques may be used to form the filtered inlet port 65, such as the formation of a powdered metal screen or

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the manufacture of a sintered powdered metal sleeve with the non-flow areas of the sintered sleeve being made impervious to flow.

[0024] Disposed within the inlet slot **60** are blocks **62**. Preferably, the blocks **62** are annular plates which are threaded on both sides. The outer threads of the blocks **62** mate with threads disposed on an inner side of the center case **55**. The inner threads of the blocks **62** mate with threads disposed on an outer side of the center mandrel **15**. The blocks are disposed on the center mandrel **15** just below a lower set of filtered inlet slots **65**. Preferably, the blocks **62** further comprise a tongue disposed on an upper end for mating with a groove disposed on the outside of the central mandrel **15**. Preferably, the blocks **62** do not completely fill the inlet slot **60**, thereby leaving a gap allowing fluid to flow around the blocks within the inlet slot.

[0025] An o-ring **17** seals an upper piston **45** / center case **55** interface. An o-ring **18** seals a lower piston **45** / center case **55** interface. An o-ring **19** seals a piston **45** / center mandrel **15** interface. Abutting a lower end of the piston **45** is an upper end of a biasing member **70**. Preferably, the biasing member **70** comprises a spring. The spring **70** is disposed on the outside of the center mandrel **15**. The lower end of the spring **70** abuts an upper end of a spring adapter **75**. The spring adapter **75** defines a tubular body. At an upper end, the spring adapter **75** surrounds and is threadedly connected to a lower end of the central mandrel **15**. At a lower end, the spring adapter **75** surrounds and is threadedly connected to a bottom sub **80**. The bottom sub **80** defines a tubular body having a flow bore therethrough. An o-ring **21** seals a spring adapter **75** / center mandrel **15** interface. A lower end of the bottom sub **80** is threaded so that it may be connected to other members of the workstring such as a nozzle valve **85** (as illustrated in FIG. 1B), or a fracture valve (as displayed in FIG. 2). An o-ring **22** seals a spring adapter **75** / bottom sub **80** interface. FIG. 1B contains a cross sectional view of the nozzle valve **85**. The nozzle valve **85** comprises a flow bore therethrough with a tapered seat for a ball that may be dropped through the workstring.

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[0026] FIG. 2 presents a sectional view of a fracture valve 100 as might be used with a filtered port of the present invention. The fracture valve 100 is seen in a run in configuration. Visible at the top of the fracture valve 100 in FIG. 1 is a top sub 110. The top sub 110 is a generally cylindrical body having a flow bore therethrough. The top sub 110 is threadedly connected at a top end to the workstring (not shown) or a packer (as shown in FIG. 1).

[0027] At a lower end, the top sub 110 surrounds and is threadedly connected to an upper end of a mandrel 115. The mandrel 115 defines a tubular body having a flow bore therethrough. Set screws 105 optionally prevent unthreading of the top sub 110 from the mandrel 115. An o-ring 113 seals a top sub 110 / mandrel 115 interface. Also at the lower end, the top sub 110 is surrounded by and threadedly connected to an upper end of a sleeve 120. The sleeve 120 defines a tubular body with a bore therethrough. Disposed between the mandrel 115 and the sleeve 120 below the top sub is an adjusting nut 122. The adjusting nut 122 is threadedly connected to the mandrel 115. Abutting a lower end of the adjusting nut 122 is an upper end of a biasing member 125. Preferably, the biasing member 125 comprises a spring. Abutting a lower end of the spring 125 is a piston 130. FIG. 2A is an enlarged partial view of a piston 130 / mandrel 115 interface. The piston 130 and the mandrel 115 define a chamber 135. Corresponding to the chamber 135 is a filtered inlet port 140 disposed through a wall of the mandrel 115. Preferably, the filtered inlet port 140 comprises one set of filter slots. Each filter slot 140 is similar to the filter slot 65 discussed above with reference to the packer 1. Disposed in the wall of the mandrel 115 below the filter slots 140 is a fracture port 145. An upper o-ring 114 and a middle o-ring 116 cooperate to seal a piston 130 / mandrel 115 interface above the fracture port 145. The middle o-ring 116 and a lower o-ring 117 cooperate to seal the piston 130 / mandrel 115 interface proximate the fracture port 145. Abutting a lower end of the piston 130 is a bottom sub 150. The bottom sub 150 is a generally cylindrical body having a flow bore therethrough. At an upper end, the bottom sub 150 surrounds and is threadedly connected to a lower end of the mandrel 115. Set screws 155 optionally prevent unthreading of the bottom sub 150 from the mandrel 115. An o-ring 118 seals a bottom sub 150 / mandrel 115

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interface. Disposed below the bottom sub **150** / mandrel **115** interface in a wall of the bottom sub **150** are jet nozzles **160**. At a lower end, the bottom sub **150** is threaded so that it may be connected to the workstring or other members thereof, such as a packer (as displayed in FIG. 1).

[0028] Referring to FIGS. 3A-3D, in operation, the packer **1** and the fracture valve **100** are run into the wellbore on the workstring, such as a string of coiled tubing, as part of a pack-off system **200**. The workstring is any suitable tubular useful for running tools into a wellbore, including but not limited to jointed tubing, coiled tubing, and drill pipe. The pack-off system **200** comprises a top packer **205**, the fracture valve **100**, the bottom packer **1**, and the nozzle valve **85** or a solid nose portion (not shown). It is understood that additional tools, such as an unloader (not shown) may be used with the pack-off system **200** on the workstring. Preferably, the top packer **205** is a slightly modified version of the bottom packer **1**. The top sub and the bottom sub are exchanged enabling the top packer to be mounted upside down in the workstring. The pack-off system may also comprise a spacer pipe (not shown) between the two packers.

[0029] In FIG. 3A, the pack-off system **200** is positioned adjacent an area of interest, such as perforations **242** within a casing string **240**. Once the pack-off system **200** has been located at the desired depth in the wellbore, a ball is dropped from the surface into the pack-off system **200** to seal the nozzle valve as shown in FIG. 3B. Fluid is injected into the system at a first flow rate sufficient to set the packers **1** and **205**. Because the flow of fluid out of the bottom of the pack-off system **200** is closed off, fluid is forced to exit the system **200** through the jet nozzles **160** of the fracture valve **100**. Flow through the jet nozzles **160** will generate a back pressure within the system. Fluid, under this back pressure, also enters the piston chambers **60** and **135** through the filter slots **65** and **140** of the packers **1** and **205** and fracture valve **100** respectively. The filter slots **65** and **140** prevent any debris in the fluid from entering the piston chambers **60** and **135**. The pistons **45** and **130** are configured such that one face of the pistons within the chambers **60** and **135** is larger than the other. This will create a net force,

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generated by the pressure, on the larger piston faces. This force will be opposed by the springs 70 and 125 and, in the packers 1 and 205, the packing elements 40. Once the pressure is sufficient to overcome the opposing forces (the spring force of the fracture valve 100 is greater than that of the packers 1 and 205), it will force the pistons 45 of the upper 205 and lower 1 packers downward (upward for the upper packer) since the system 200 and thus the center mandrels 15, blocks 62, center cases 55, and lower gage rings 50 are held in place by the workstring. This forces the packing element compressors 30 and upper gage rings 5 to move downwardly (upwardly for the upper packer). The upper gage rings 5 push down (up for the upper packer) to set the packing elements 40 of the upper and lower packers 1 and 205. The packing elements 40 are shown set within the casing 240 in **Figure 3C**.

[0030] After sufficient pressure has been applied to the pack-off system 200 through the bores of the center mandrels 15 to set the packing elements 40, the fluid injection rate is increased into the system 200. From there fluid enters the annular region between the pack-off system 200 and the surrounding casing 240. The injected fluid is held in the annular region between the packing elements 40 of the upper 205 and lower packers 1. Fluid continues to be injected, at this higher rate, into the system 200 and through the jet nozzles 160 until a greater second pressure level is reached. This second pressure causes the piston 130 of the fracture valve 100 to move upward along the mandrel 115. This, in turn, exposes the fracture port 145 to the annular region between the pack-off system 200 and the surrounding casing 240 as shown in **FIG. 3D**. A greater volume of fracturing fluid can then be injected into the wellbore so that formation fracturing operations can be further conducted.

[0031] If any debris should deposit on the filter slots, it may be purged when the system is reset by de-pressurization. This is due to the fact that as the pistons 45 and 130 are urged back to their run in positions, fluid will be forced from the chambers 60 and 135 of the packers 1 and 205 and fracture valve 100 back through the filtered slots 65 and 140 into the center mandrels 15 and mandrel 115 respectively.

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[0032] The filtered inlet ports shown in FIGS. 1-3 may be used with any hydraulically operated tool. While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.